Physiology of electrical and Synaptic transmitters in Neurons. (Transmission of nerve impulse)

Introduction → The most important characteristic of a living organism is reacting to an environmental changes, Such changes are called Stimulus which gives rise to response. These responses are passed by the functioning of Central nervous system which includes the brain and spinal cord.

Nervous System includes a large no of neurons which performs the main function of conduction and transmission of nerve impulse. After embryonic life the neurons do not divide, remain in permanent interphase throughout the entire life of organism. They undergo changes in volume, complexity of its processes and functional contacts, but the no. of neurons do not increase by cell division. The neurons or nerve cells store instictive and learned information (eg conditioned reflex, memory etc.)

Structure of a neuron → A neuron is made up of -

1. The cell body (PeriKaryon) which may emit one or more outgrowths called dedrite
2. dendrites are outgrowths which carry nerve impulse centripetally.
3. Axon - It carries nerve impulse centrifugally to the next neuron or effector

A neuron (Axon) may be covered by a mayelin Sheath after emerging from PeriKaryon. The neuron terminates, ramifying in the endings or it may end in bulb like Structure called Synaptic bulb.

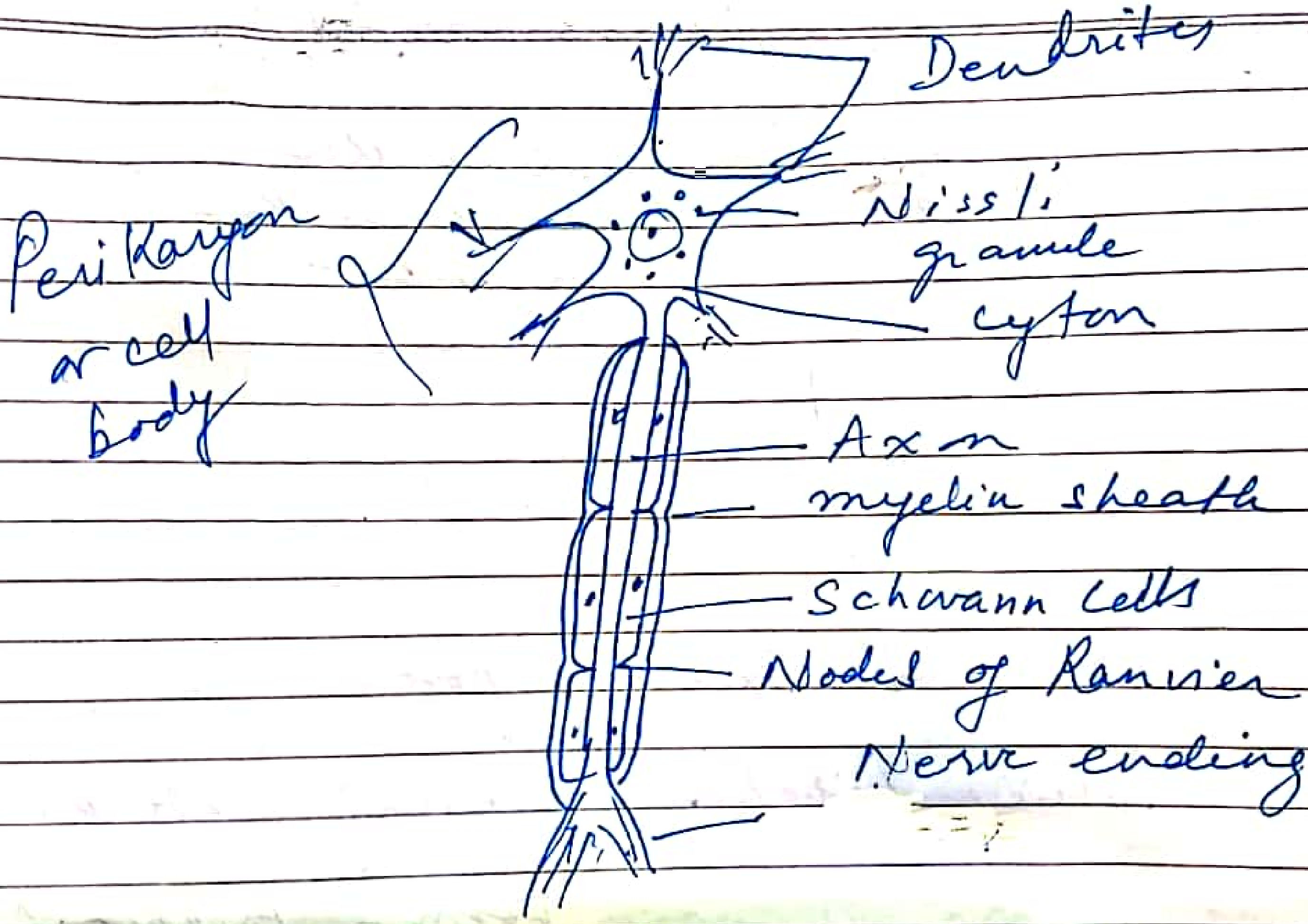


Diagram showing Structure of a neuron.

Nerve fibres are non myelinated when wrapped only in Schwann cells, myelinated nerve fibres have a myelin sheath that consists of a multilayered lipoprotein system. The myelin sheath is interrupted at Nodes of Ranvier. The distance between nodes varies with the diameter of fibres. The distance between two nodes is called internode and it is the segment of myelin that is produced and contained within a single Schwann cell. The internode is 0·2mm in a fibre of 4 um about 1·5 mm in a fibre of 12 um and 2·5 um in one of 15 um.

Within the internode, incisures go across the myelin sheath where the myelin leaflets have a deeper disposition. At the node the myelin is loosely arranged and small zone of axon is in direct contact with extra cellular fluid. The myelin sheath acts as an insulator and as a consequence the myelinated fibres conduct nerve impulses at a much faster rate than unmyelinated fibres.

The diameter of the fibre also influences the conduction rate. The nerve fibres are classified into 3 groups according to their diameter A, B, and C. C fibres are unmyelinated. The diameter may vary from 20 um in A fibres to less than 1 um in C fibres, and the conduction velocity varies from 100 to 2 meters or less/second. The rate of conduction of the nerve impulse follows a ~~linear~~ ~~se~~ linear relationship with the fibres diameter in mammalian myelinated fibres and it is also related to the internode distance.

Conduction of nerve impulse – The Action Potential.

When a nerve fibre is stimulated a profound change is produced in the electrical properties of the surface membrane and in the steady potential, a wave of depolarisation is conducted. The resting potential changes suddenly, at the point of stimulation the potential inside the membrane becomes positive.

It has been found that at the point of stimulation there is hundred fold increase in permeability to Na^+ which reached its peak in 100 micro seconds. at the end of this period the membrane again becomes impermeable to Na^+ ions but K^+ permeability increases and this ions comes out again ~~repol~~ repolarising the nerve fibres. In short it may be said that during depolarisation Na^+ enters and during repolarisation K^+ comes out, complete restoration of electrical balance takes a longer time after this electrical event.

The propagation of nerve impulse is explained by local circuit theory At the point of stimulation the area becomes depolarised (negative outside) and acts as a sink towards which the current flows from the adjacent areas. This wave of depolarisation advances along the nerve fibre at a rate of conduction characteristic of each fibre, at the same time repolarisation also occurs simultaneously and rapidly so that only a fraction of nerve fibre is depolarised at a time. In the recovery period sodium leaves the cell by action of sodium pump and potassium reenters to restore steady state. This recovery is produced by the expense of high energy phosphate bond bonds (active transport across membrane using adenosine tri phosphate or ATP)

The action potential that develops in the nerve fibre has some several important characteristic features such as -

(1) The stimulus produced a slight local depolarisation in the fibre which after reaching a certain threshold of activation produces spikes of the same amplitude, if the intensity of stimulus is the increased, the height of spike always remains the same, this phenomenon is known as all or none response.

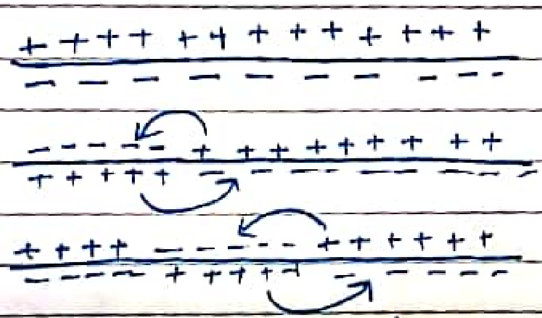
(2) The nerve impulse is non decremental means that the amplitude of the spike does not decreases all along the length of nerve fibre. The action potential is thus well adapted to conduction over long distance without losses.

(3) once a nerve impulse has passed over any point of the fibre, there is a refractory period during which it cannot react to another stimulus.

Saltatory conduction in nerve fibre -

In myelinated fibres it has been observed that the local circuits occurs only at the nodules According to this saltatory theory, at the internode the nerve impulse is conducted electrically and at each node the action electronically

Potential is boosted to the same height by ionic mechanisms. The amount of Na^+ and K^+ exchanged is greatly reduced and the network required is much less. Stimulation of myelinated nerves has much less threshold of stimulation than the non myelinated nerve fibre. It has been found that the nerve impulse can jump across one depolarised node to another in a single direction.

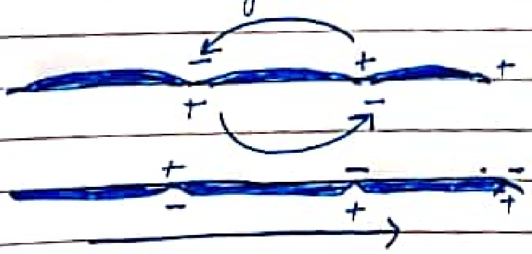


A unexcited nerve fibre

B excited nerve fibre

C movement of action potential and recovery

Diagram showing local circuit theory of propagation of the action potential (ABC) in unmyelinated neurons and muscle fibres.



Arrows showing the direction of impulse propagation.

Diagram showing node to node saltatory conduction. In large nerve fibres ionic exchange occurs very fast as compared to conduction in unmyelinated nerve fibre.

In addition to the all or none response, there is another type of electrical activity called graded response in the the impulse is not propagated and the amplitude varies with the intensity of stimulus. This is most frequent in central nervous system.

Key points

1. Neurons are the main cells of nervous system
2. They do not divide and help in conduction of nerve impulse
3. The conduction of nerve impulse takes place by two methods

(i) The electrical method of nerve impulse transmission

(ii) The chemical method.

The electrical method of impulse transmission takes place by 2 methods

1. Local circuit theory and
2. The Saltatory theory

In local circuit method there is a ~~contin~~ continuous exchange of positive and negative charges across the cell membrane. It takes place in unmyelinated nerves.

In Saltatory method the action potential jumps from one node to another in a myelinated nerve fibre.

A graded response is also observed in these cases.

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